Next Generation Aura OMI NO_2 & SO_2 products

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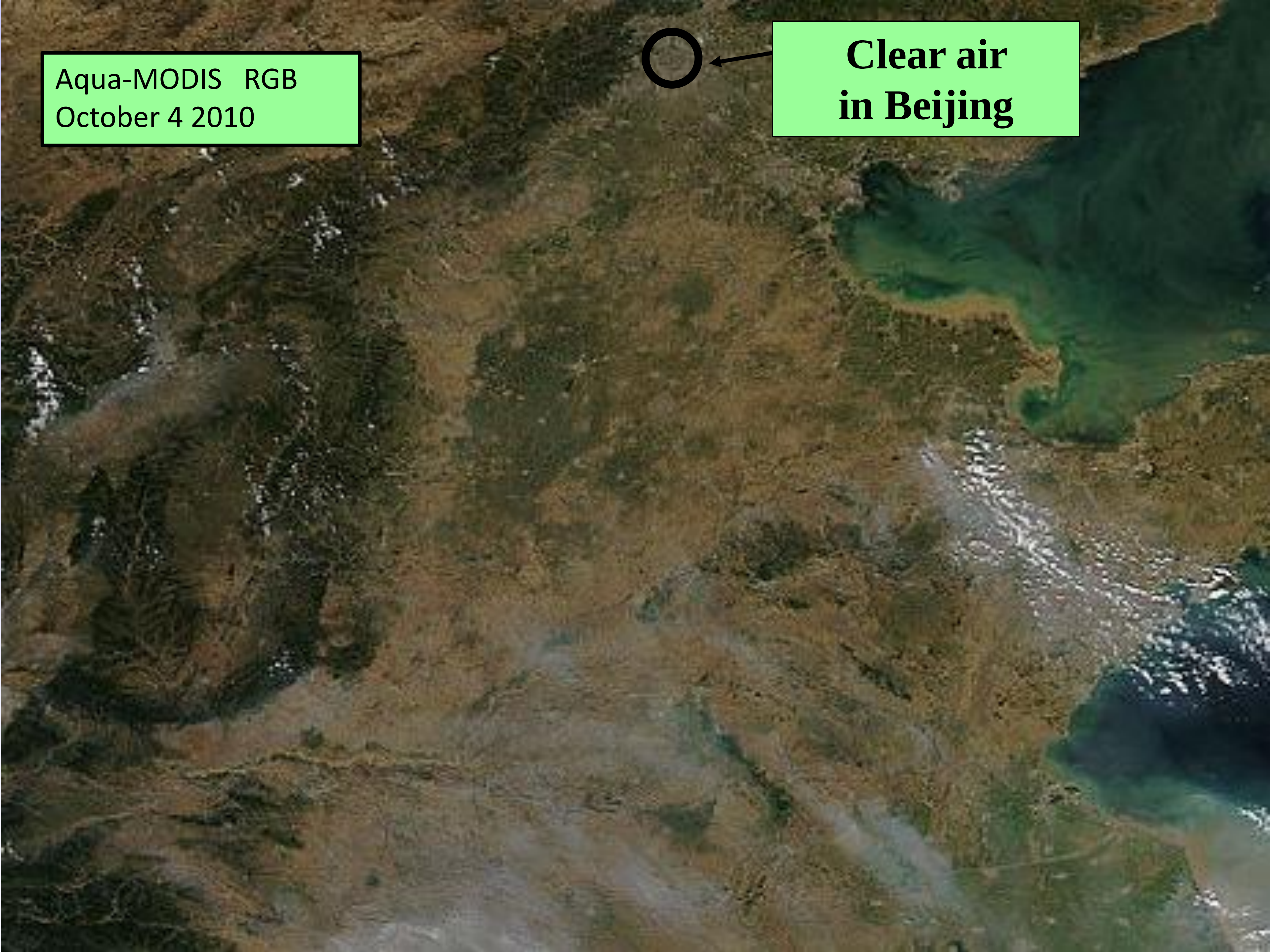
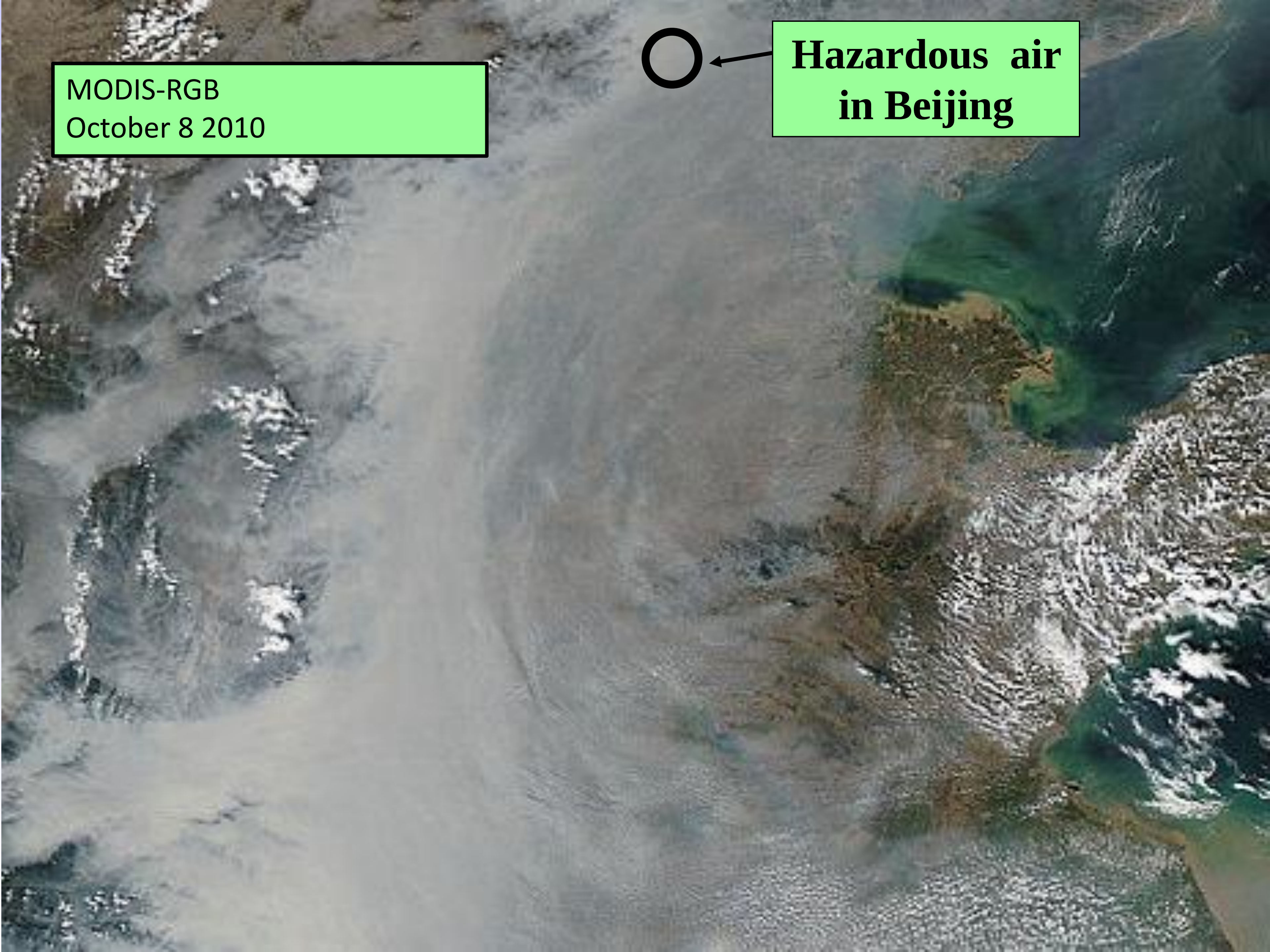
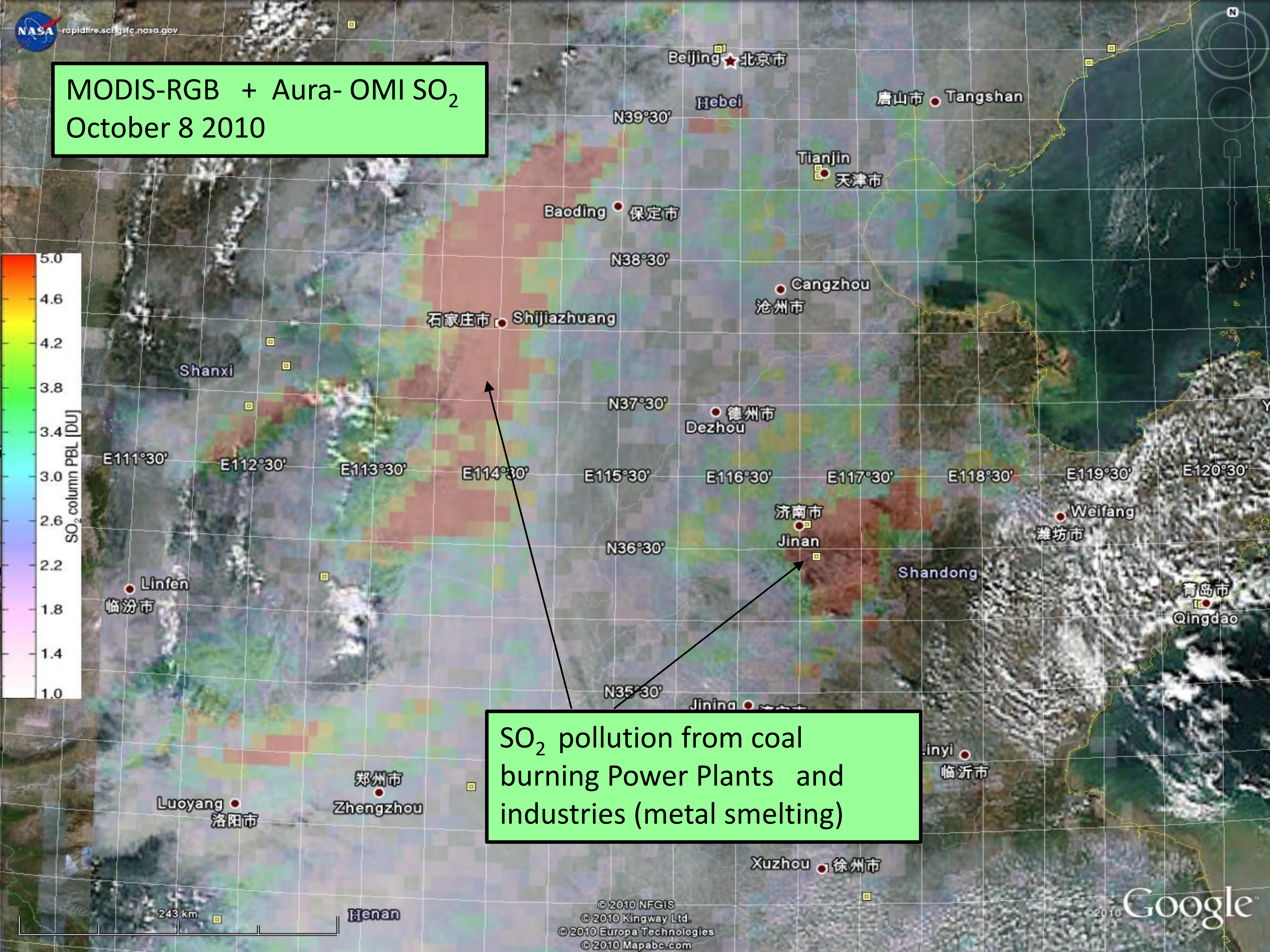
A-Train Symposium

New Orleans, October 26 2010


Aqua-MODIS RGB
October 4 2010
Clear air
in Beijing

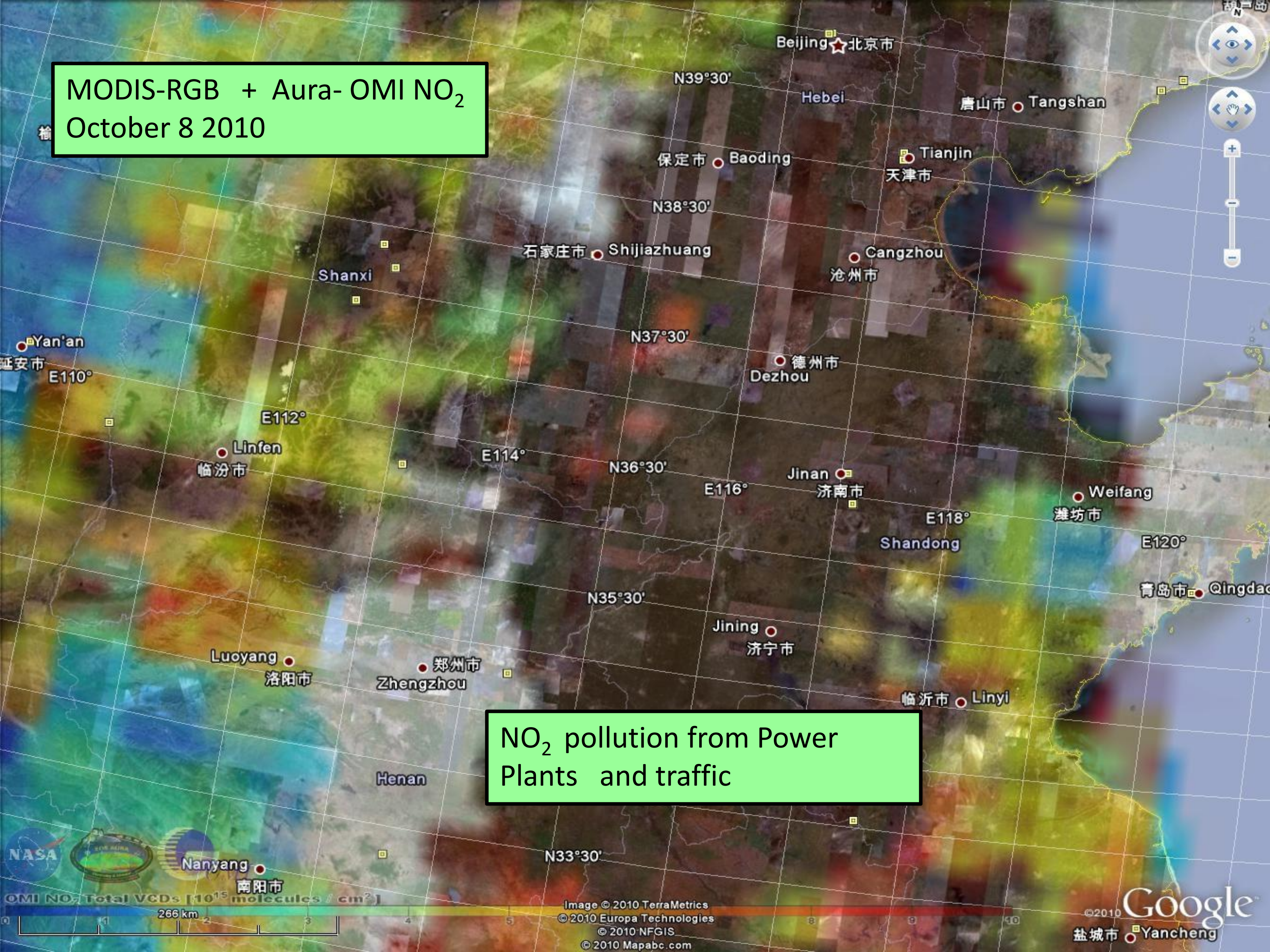

MODIS-RGB
October 8 2010
Hazardous air
in Beijing

MODIS-RGB + Aura- OMI SO_2
October 8 2010



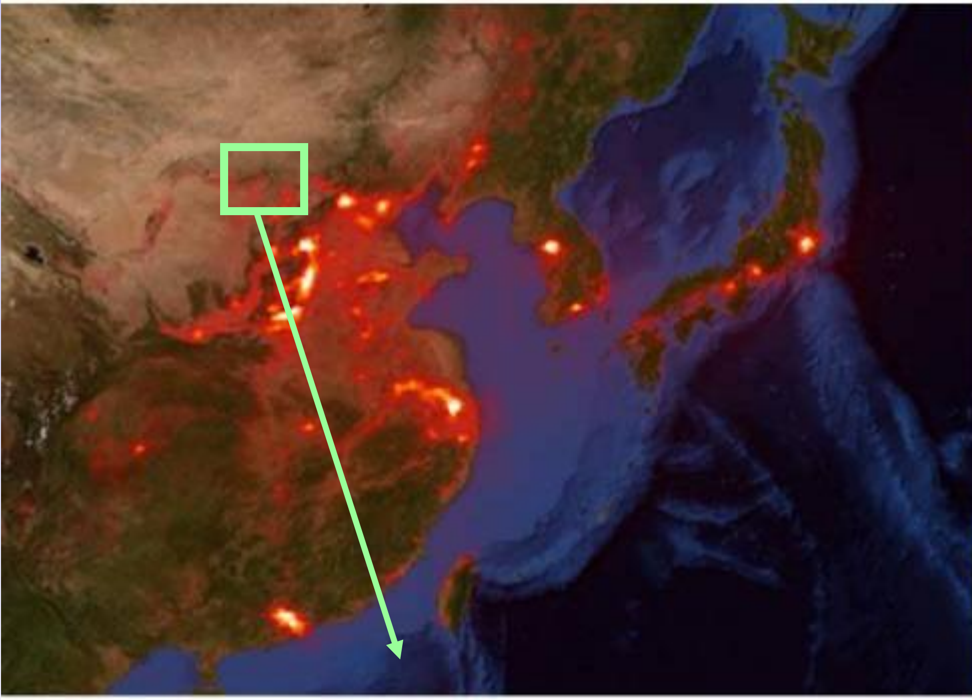
SO_2 pollution from coal burning Power Plants and industries (metal smelting)

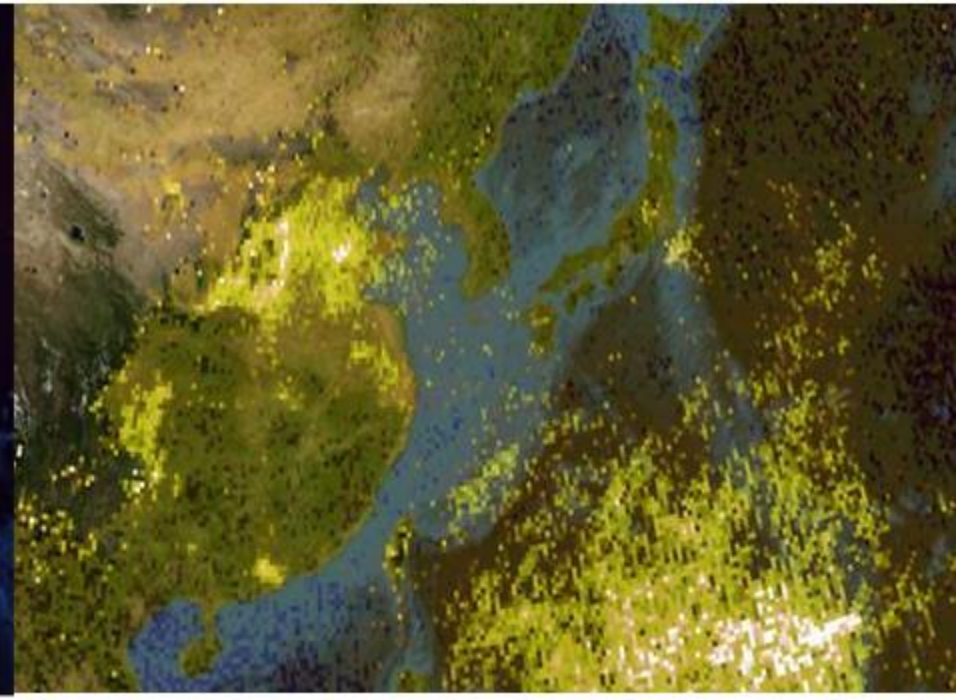
MODIS-RGB + Aura- OMI NO_2
October 8 2010

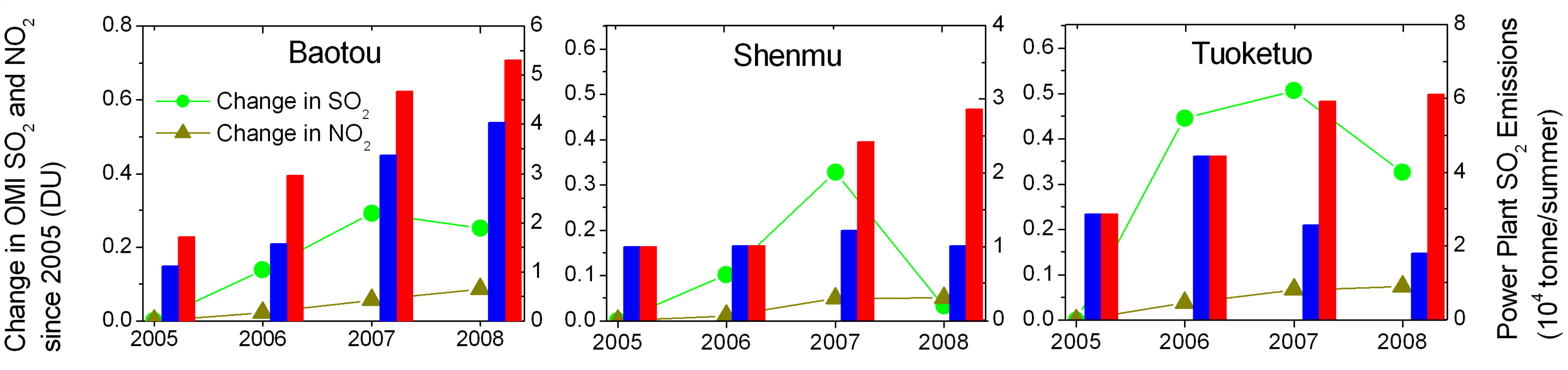


NO_2 pollution from Power Plants and traffic

The measurement of both SO_2 and NO_2 is an essential component of the Aura mission







OMI operational SO_2 and NO_2 data

- 2 different OMI NO_2 products (KNMI and GSFC)
- Current SO_2 and NO_2 algorithms are not consistent
- SO_2 height not provided
- OMI NO_2 and SO_2 data (except volcanic) are only used for low cloud radiance fractions (CRF < 0.2-0.3)
- Users proposed improvements (e.g. Lee et al., 2009 for SO_2; Lamsal et al., for NO_2].
- Averaging Kernel information is not operationally provided

Re-processing Goals:

- Significantly improve the OMI Level-2 SO_2 and NO_2 data records by exploiting geophysical information contained in OMI hyperspectral measurements and other high spatial resolution cloud and aerosol data from A-train sensors;

- Provide critical information (e.g. Averaging Kernels) for evaluation of chemistry-transport models, for data assimilation, and to impose top-down constraints on the SO_2/NO_2 column ratios that characterize anthropogenic emission sources;

- Develop enhanced Level-3 SO_2 and NO_2 data products to serve the interests of a broader atmospheric composition and air quality user community;

- Continue and improve our long-term explosive volcanic SO_2 climate data record that started with TOMS in 1978, continues to present with OMI, and will continue with NPP/OMPS, with improved explosive volcanic SO_2 emission height estimates;

- Continue and improve near-real-time volcanic SO2 and ash detection for aviation decision support

Measurement of trace gas column N: DOAS vs. Direct Fitting

DOAS: $\ln I_{TOA}$ vs. σ_a

$$\frac{\partial \ln I_{TOA}(N,z)}{\partial \sigma_a} = -N\,m \;= \mathbf{SCD}$$

Direct Fitting:

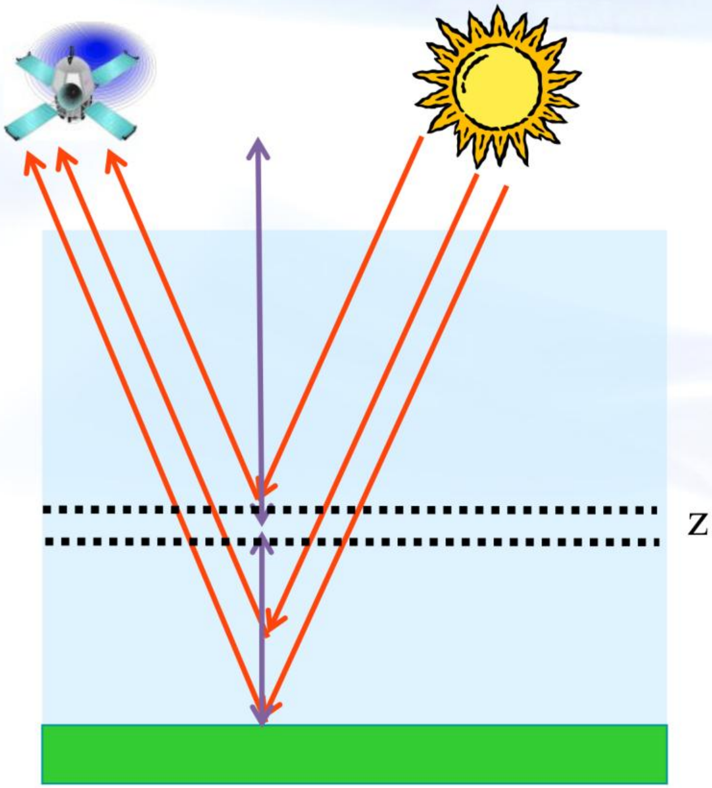
$\ln I_{TOA}$ vs. N Weighting Function

$$\left.\frac{\partial \ln I_{TOA}(N,z)}{\partial N}\right|_{N=0} = -\sigma_a\, m$$

m is the air mass factor (AMF).

$$m = \left(1 - \frac{I_a(z)}{I_{TOA}(N,z)}\right) m_g$$

$$I_{TOA}(N,z) = I_a(z) + I_b(z)e^{-m_g \tau_a}$$



Direct Fitting for O_3 and SO_2

- Minimize the difference between measurements and model simulation by adjusting retrieval parameters (O_3 and SO_2 columns, and Ring and reflectance parameters) iteratively

$$\ln I_m - \ln I_{TOA} = \sum_{p=1}^{n} \left. \frac{\partial \ln I_{TOA}}{\partial X_p} \right|_{X_p = X_{p_i}} \Delta X_p + p_{\mathrm{rrs}}\, \sigma^{\mathrm{rrs}}$$

$$+ \left(\Delta F_c + \sum_{k=1}^{2} c_k (\lambda - \lambda_0)^k \right) \left. \frac{\partial \ln I_{TOA}}{\partial F_c} \right|_{F_c = F_{c\,i}} + \varepsilon$$

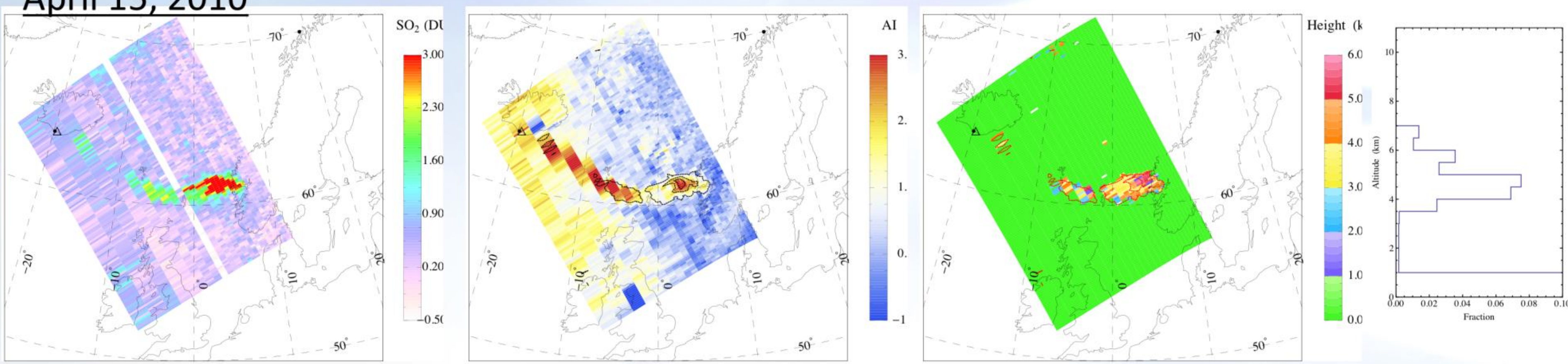
- Aerosol Index : spectral slope c_1, which quantifies the spectral contrast of the apparent reflectance (i.e., the combined effect of ground reflection and back-scattering by clouds/aerosols) of an IFOV at the lower atmospheric boundary

Improvement in Accounting for Profile Shape Effect

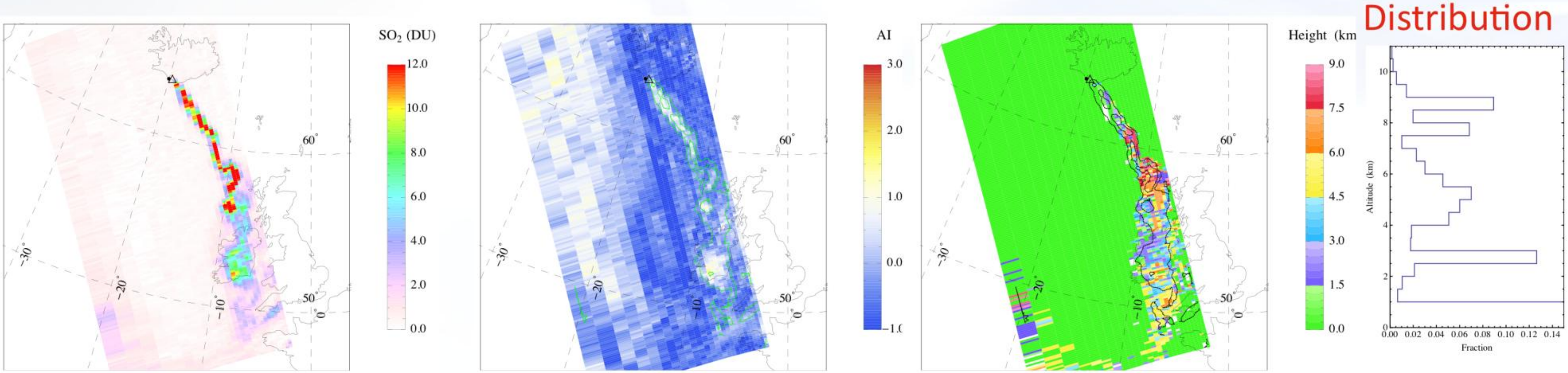
- BUV measurements contain information of SO_2 plume height in addition to its column amount
- This information can be extracted from hyper-spectral BUV measurements.
  - For SO_2 in the troposphere and up-to the lower stratosphere, spectral measurements in 300 – 330 nm are needed to extract the height information.
  - For large SO_2 column, this range can be narrowed to 310 – 330 nm.
- Height information needed for accurate quantification of column amount

Eyjafjallajökull Plumes

April 15, 2010

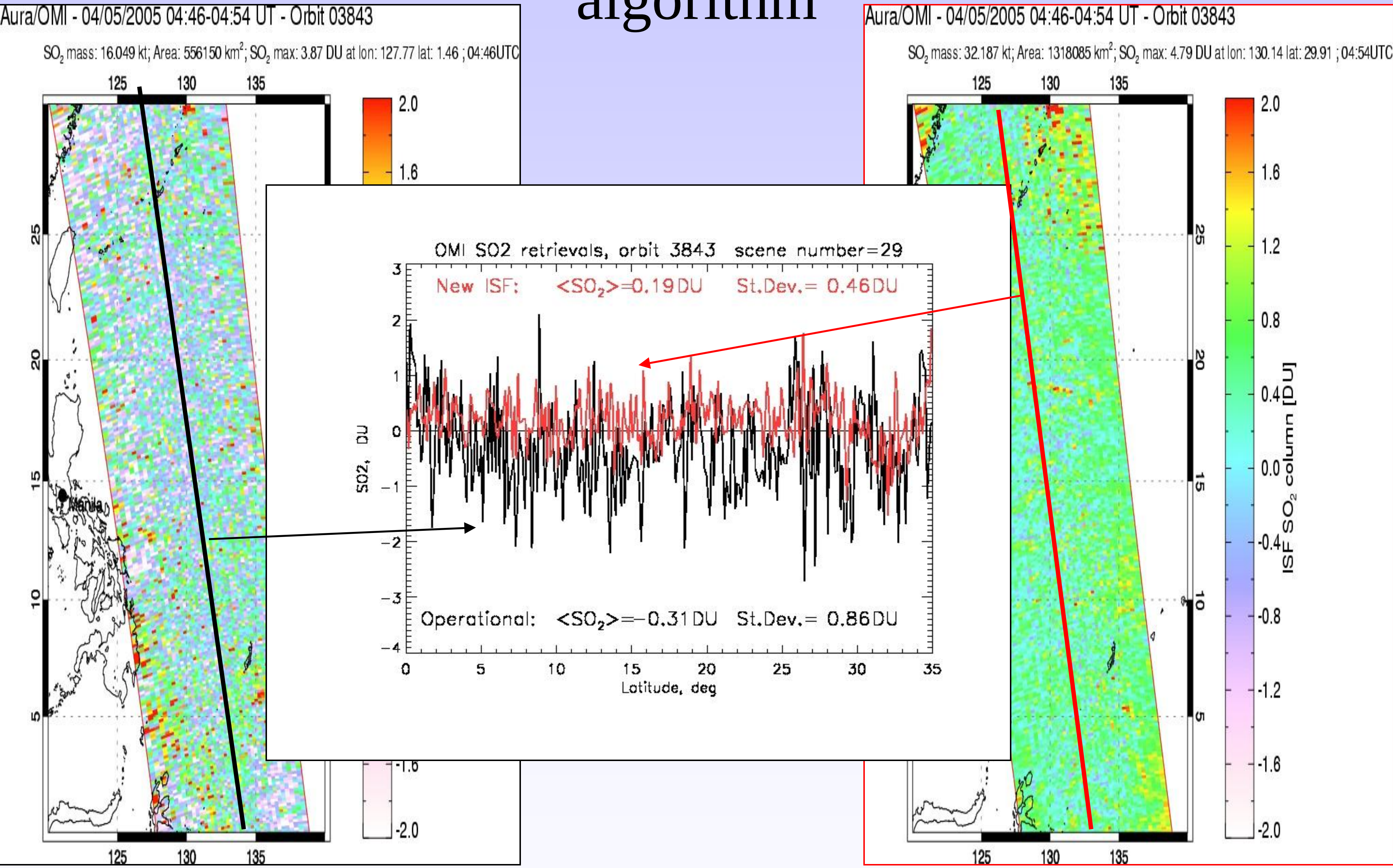


SO2 Aerosol Index Height Height Distribution



May 5, 2010

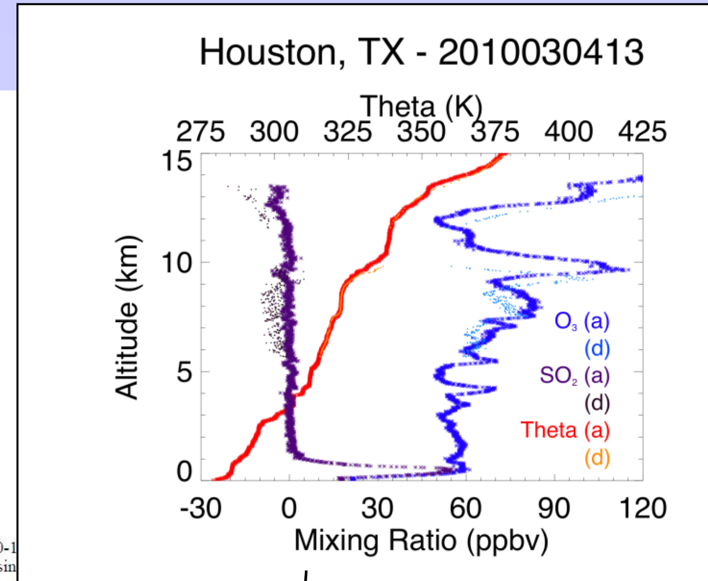
Background noise is reduced with the new DSF algorithm

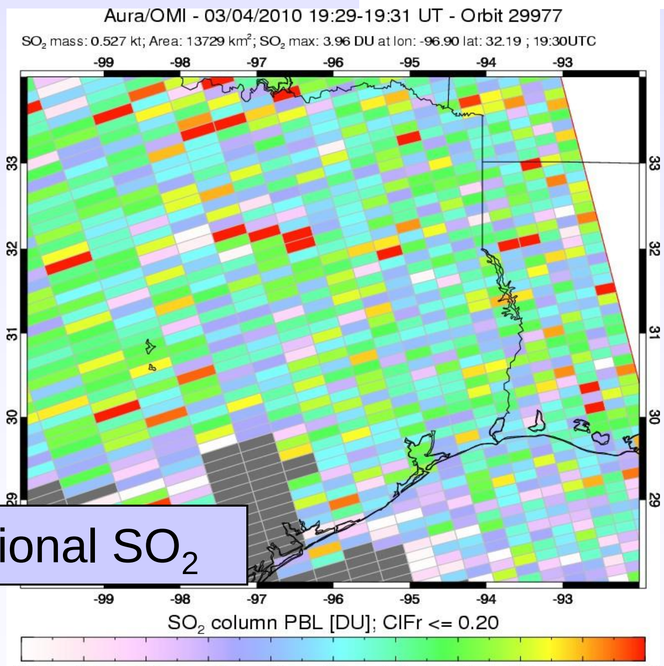


More sensitive OMI Direct Spectral Fit SO_2 retrievals

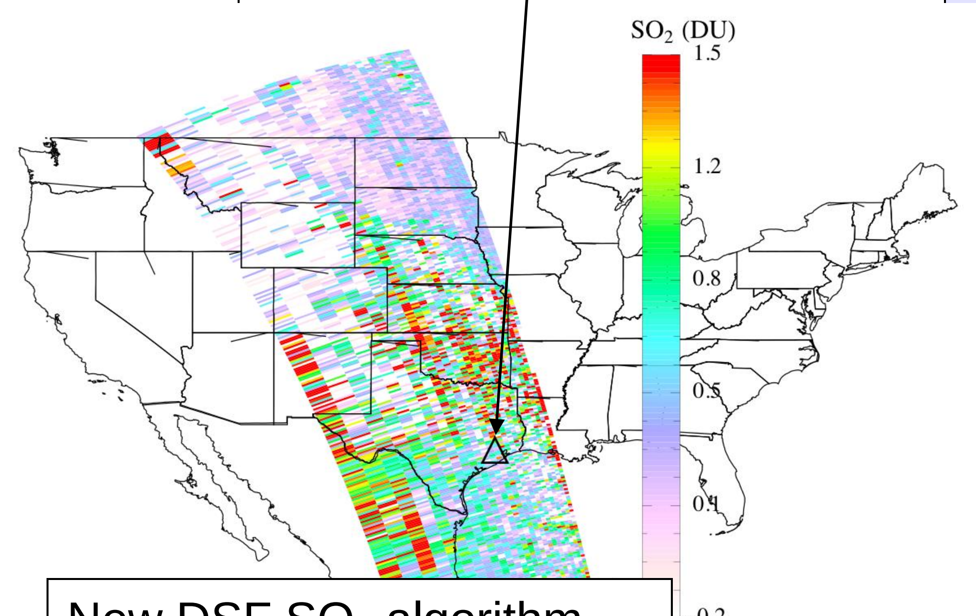
Dual sounding O_3-SO_2 technique,
[G. Morris et al 2010]

Figure 3. The dual O_3/SO_2 sonde payload. From left to right are the Vaisala RS80-1 diosonde, the unfiltered ECC ozonesonde, and the SO_2 filtered ECC ozonesonde usin EnSci CrO_3 filter.





Operational SO_2



New DSF SO_2 algorithm
[Yang GRL 2010]

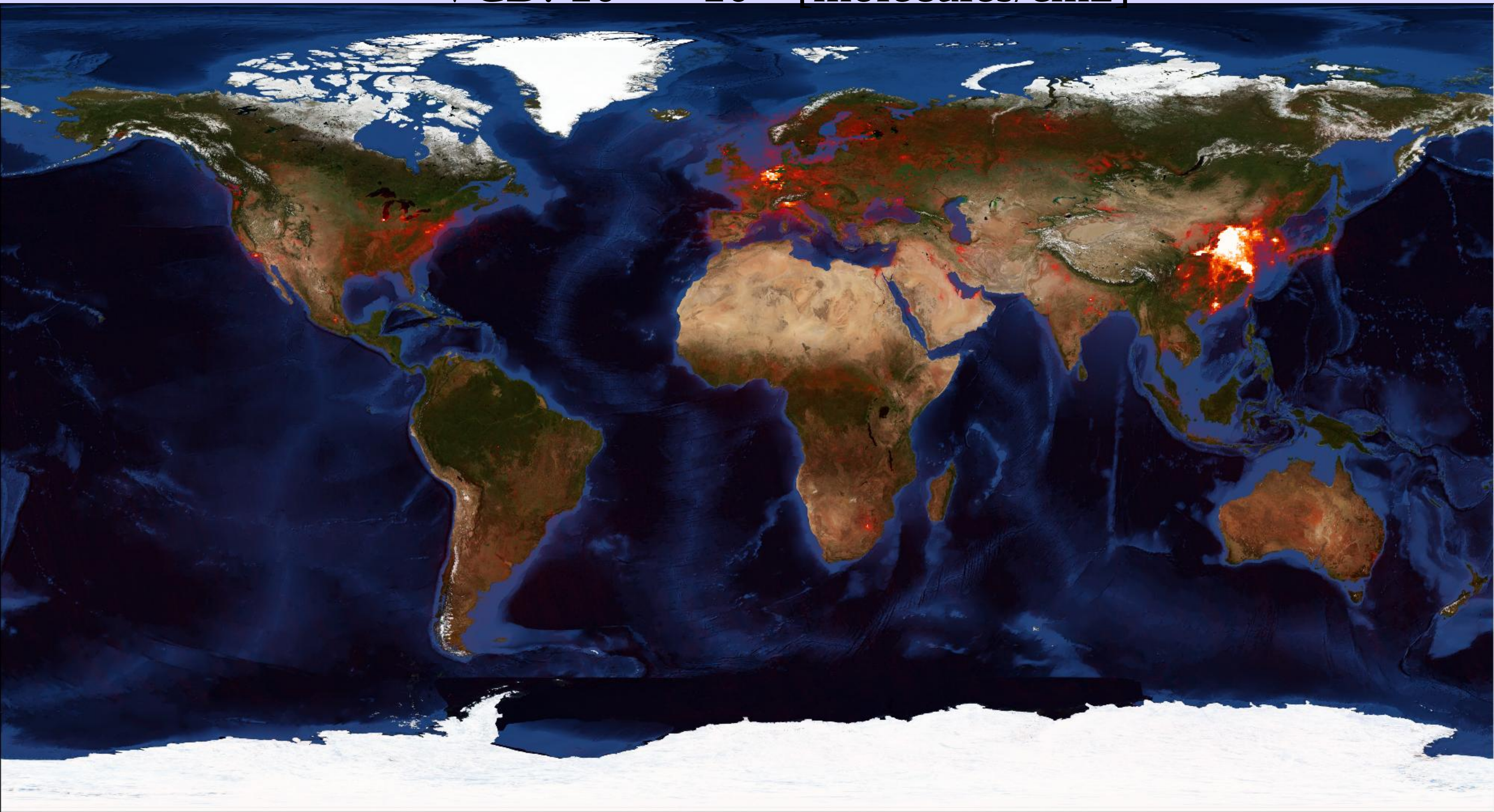
OMI operational NO_2 data

Standard (GSFC) and NRT (KNMI) NO_2 products :

Tropospheric and Stratospheric vertical column densities (VCD)

assuming climatological (GSFC) and forecast (KNMI) vertical profiles

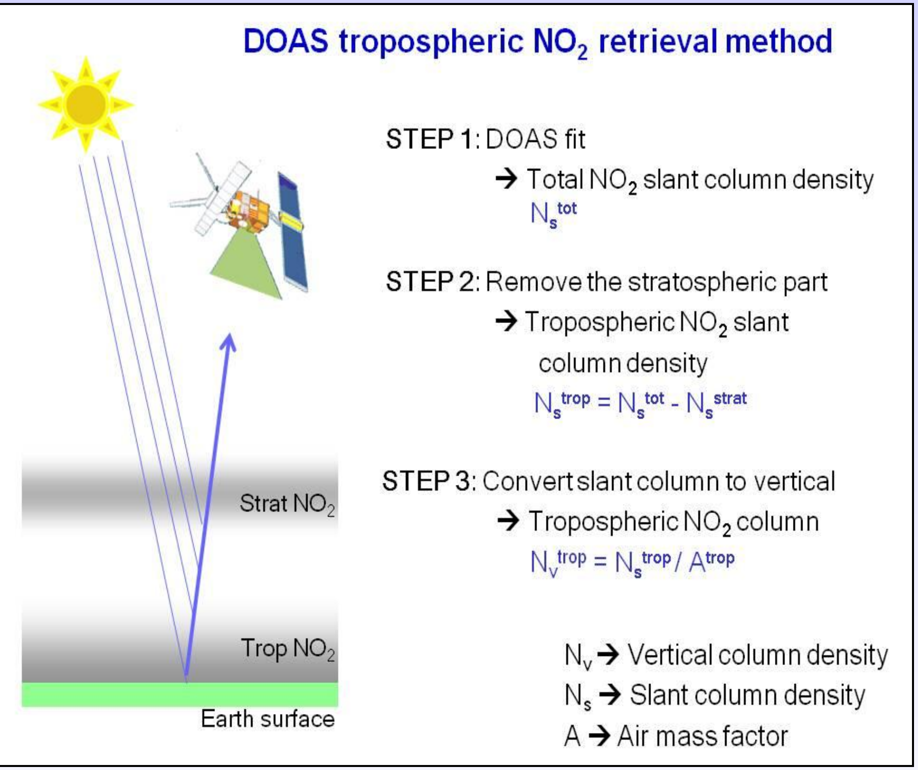
VCD: 10^{15} – 10^{17} [molecules/cm2]

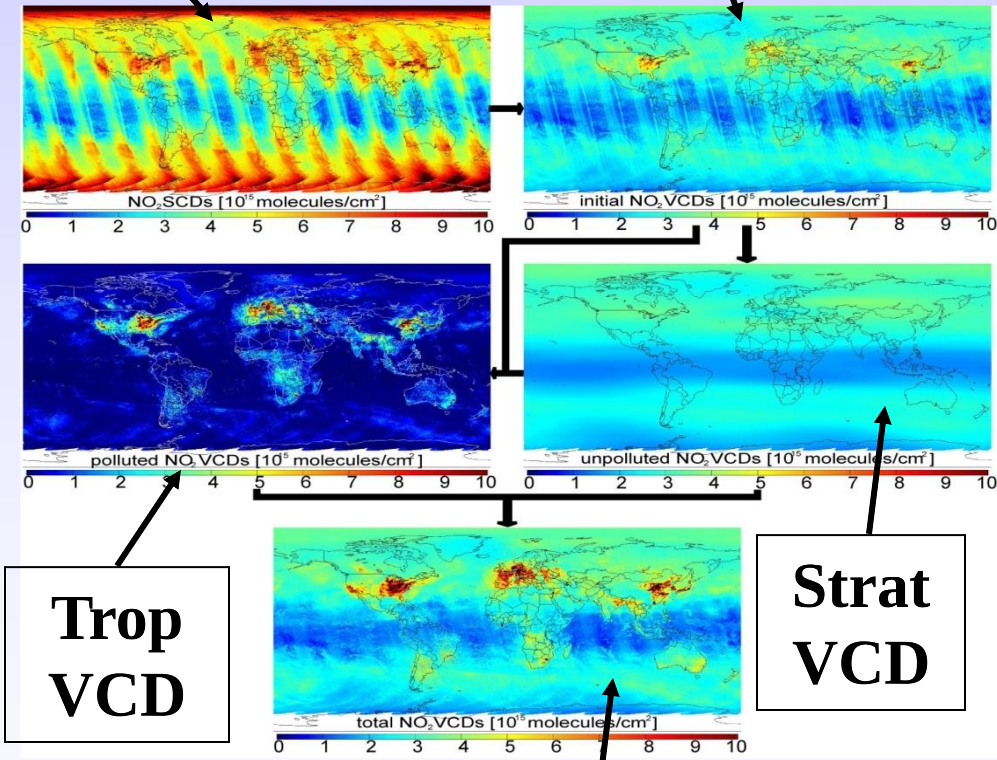


OMI operational NO_2 algorithm

Measured Slant Column Density (SCD)

VCD= SCD/AMF





Trop VCD

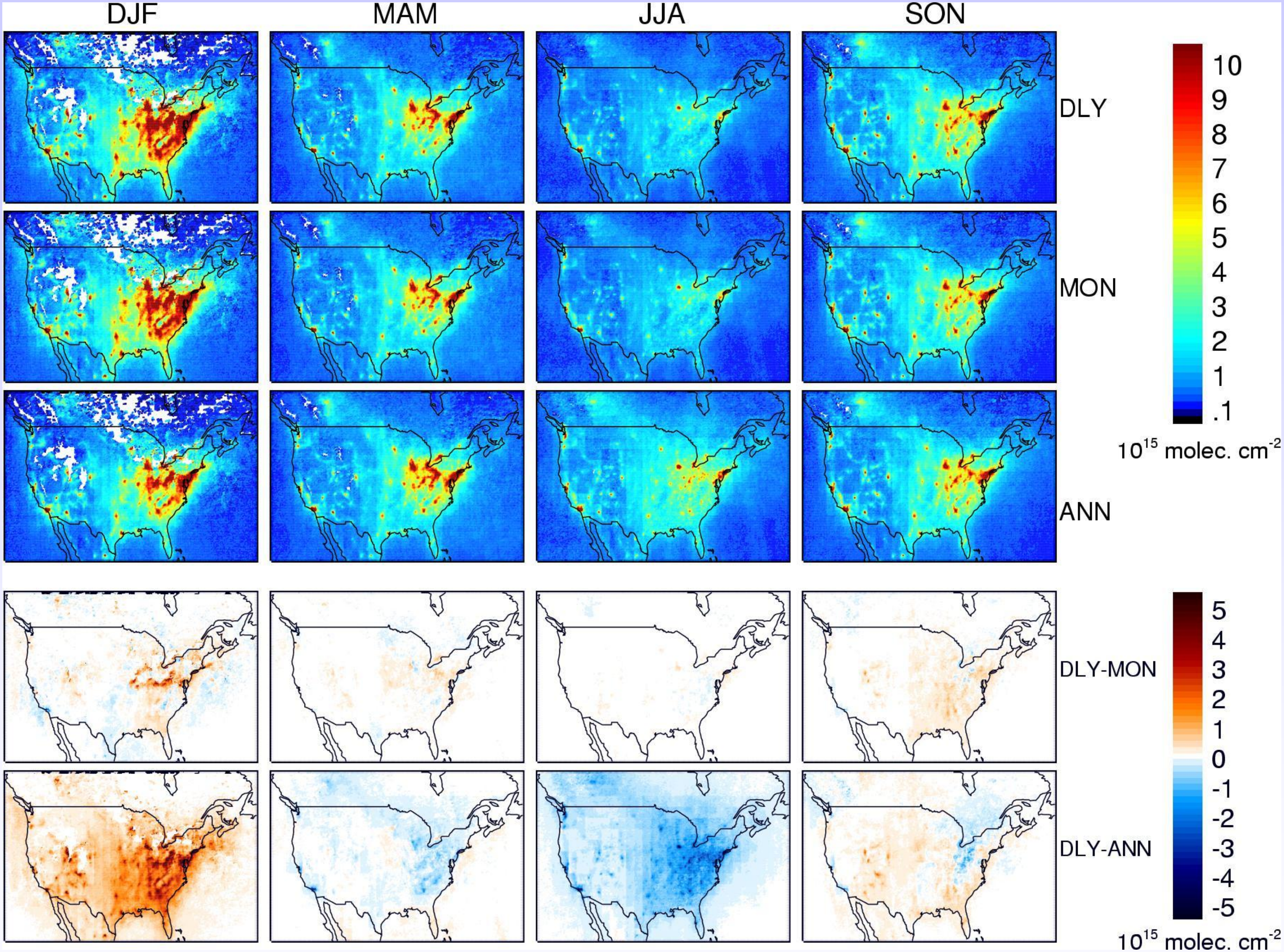
Strat VCD

Strat+Trop VCD

NO_2 algorithm improvements:

- Better separation of stratospheric and tropospheric NO_2 columns
- Using Monthly GMI profiles
- Better cloud/aerosol corrections
- Better surface corrections
- Provide consistent Averaging Kernels
- instrumental characteristics while maintaining a high-quality data products.

Annual mean profile responsible for seasonal bias



Averaging kernel definition

$$S = \int dp\ \mu(p)\,\rho(p)$$ = <u>slant column</u> [*Palmer et al*. [2001],

$$V = \int dp\ \rho(p)$$ = <u>vertical column</u>

where

$\mu(p)$ = <u>scattering weights</u> (aka Jacobians, dAMFs, etc) (*a priori* functions of pressure p; also of viewing geometry, albedo, clouds, etc)

$\rho(p)$ = <u>trace-gas mixing ratios</u> (*a priori* functions of pressure)

If M = S/V is the air mass factor, then define

$$A(p) \equiv \mu(p) / M$$ = <u>averaging kernel</u> [*Eskes & Boersma*, 2003]

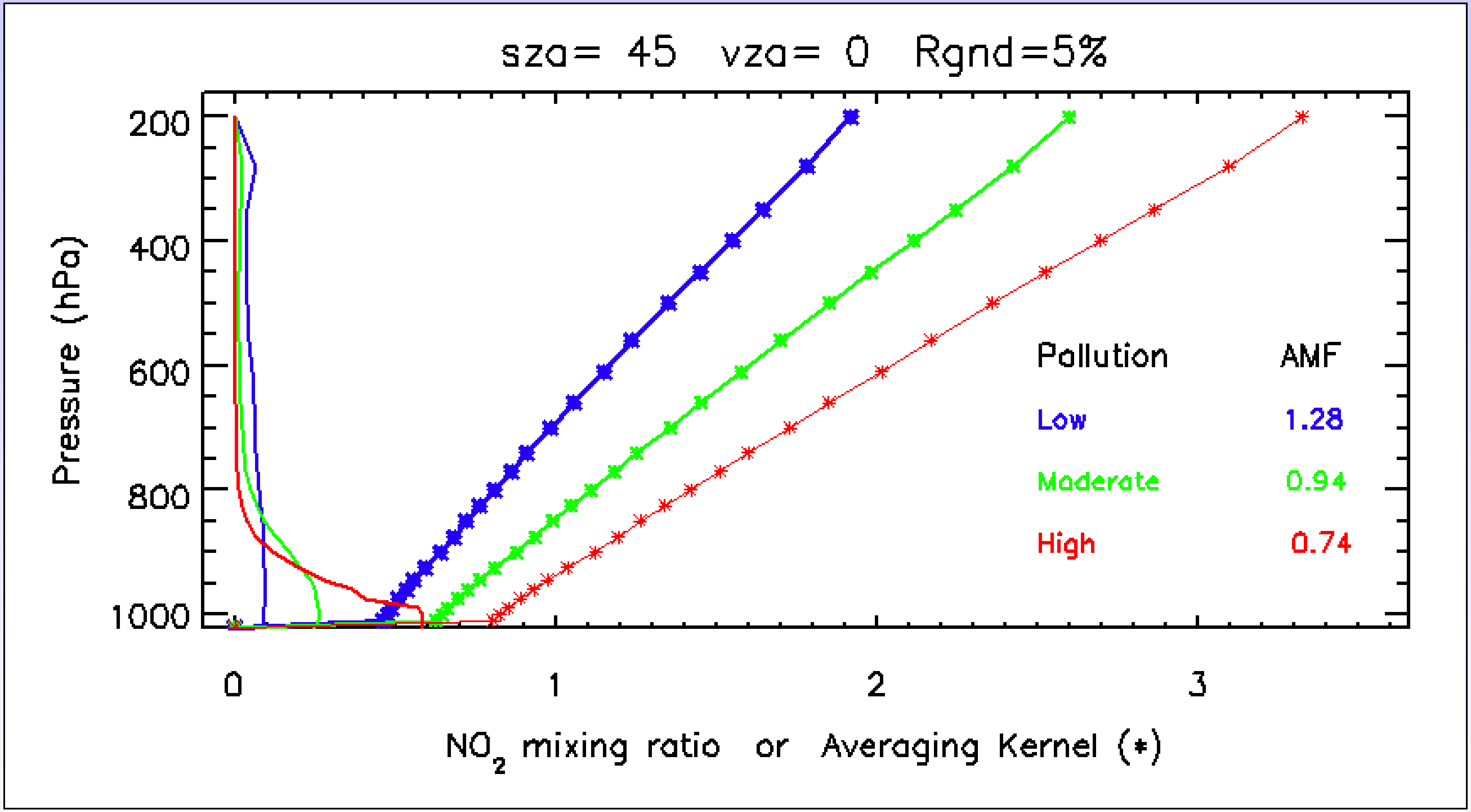
A(p) shows retrieval sensitivity to the trace gas at a given pressure level.

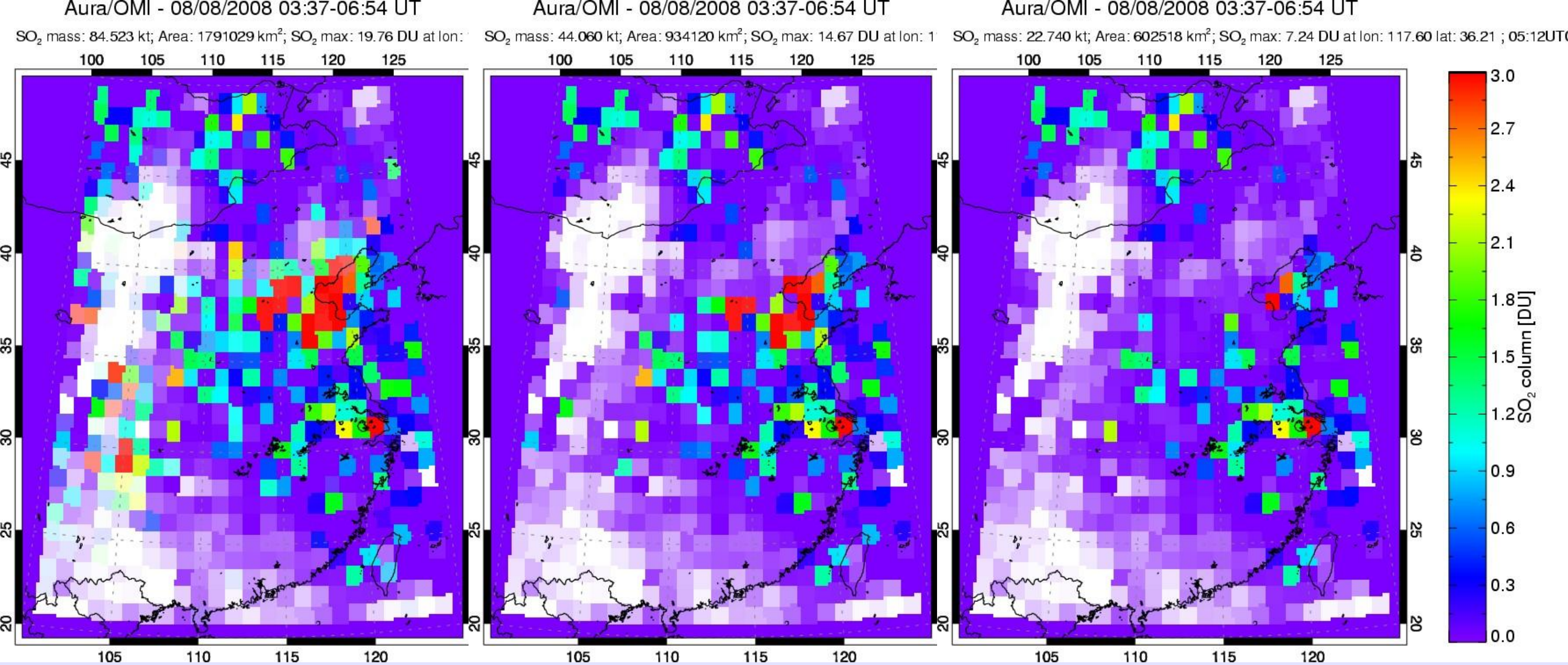
To compare an OMI retrieved vertical column V_{OMI} to an independent set of modeled or measured mixing ratios $\rho'(p)$, compute the ratio of V_{OMI} to V_{AK}, where

$$V_{AK} = \int dp\ A(p)\,\rho'(p)$$

The ratio V_{OMI}/V_{AK} will be independent of the *a priori* mixing ratio profile $\rho(p)$.

Averaging kernel examples: Clear sky



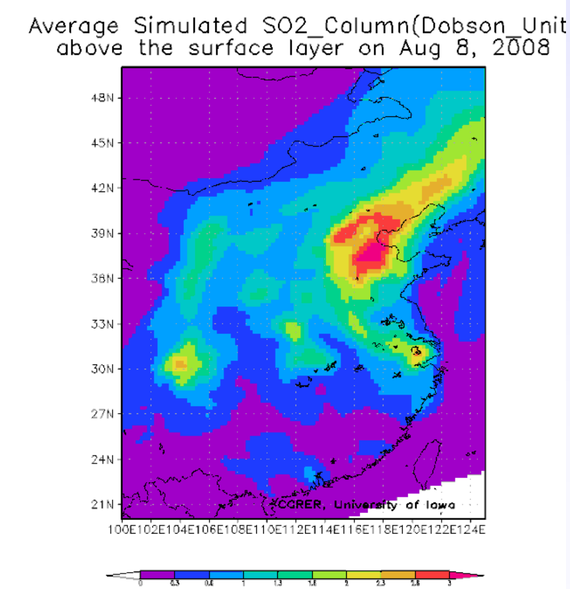


No OMI CldFrac filter

OMI CldFrac <0.5

OMI CldFrac <0.3

(used in monthly OMI maps)



-Satellite data should provide better corrections for partly cloudy scenes: filtering cloud pixels removes useful information;

- A-priori information is needed on cloud effective height, aerosols and SO_2 profile shapes

- Model fields should be re-sampled consistently with satellite measurements (applying the same cloud filter)

Implementation

- New version of the standard NO_2 data - January 2011
  - Including AK
  - Monthly NO2 profiles
  - Other improvements - see Poster by Ed Celarier
- Releasing level 3 SO_2 data - January 2011
- Next generation NO2 and SO2 products - 2012 ROSES Aura ST proposal pending